Decentralized Water Infrastructure for Growing Urban Neighborhoods:
Environmental, Social, and Financial Implications

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Abstract

- Purpose
  - Evaluate financial, environmental, and social impacts of decentralized water technologies (on-site/shared systems) based on multiple neighborhood growth scenarios
- Study Area
  - Bankhead: low-income neighborhood where water affordability is a critical issue
- Methods
  - System dynamics incorporating land-use dynamics, fixture retrofitting, water demand projection, and impacts of decentralized water technologies
- Results
  - Decentralized technologies have potential to reduce potable water demand up to 44%
  - Shared rainwater and graywater systems can be sustainable and economically viable solutions to meet increasing water demand in a growing urban neighborhood

Sustainable Urban Water Management (SUWM)

- Principles of SUWM
  - Incorporate a number of alternative water sources
  - Distribute decentralized treatment plants across urban areas
  - Integrate supply, sewer disposal, and stormwater as components of a system
  - Consider multiple sustainability indicators of system performance

Conventional urban water cycle
("take, make, waste approach")

Sustainable urban water cycle

Decentralized Urban Water Technologies

- Types of Technology
  - Rainwater harvesting / Graywater reuse / Wastewater recycling
- Scales
  - On-site / Semi-centralized (Shared)
- Benefits
  - Increased efficiency of resource use and reduced ecological footprint
    - 30-60 % decrease in water demand; reduced water treatment and transfer costs
  - Enhanced water security through source diversification and multiscale networks
    - Lower capital intensity and shorter construction time; rapid respond to external shocks
  - Better opportunities to adjust the water system to local conditions
    - Low-tech, low-cost, and flexible service boundary

Study Area

- Challenges in Atlanta Water Management
  - Growing population and urban sprawl
    - 2.5 million more residents within the next 25 years (Atlanta Regional Commission)
  - Lack in diversity of water supply options
    - A single water source, Lake Lanier, supplies over 70% of metropolitan water demand
  - Nation’s highest combined water price
    - $325.52 estimated monthly water bill for a typical four-person family
  - Tristate water wars
    - Inter-state dispute concerning the use of two shared river basins (Alabama & Florida)
  - A century-old infrastructure system

Study Area

- Bankhead Neighborhood
  - Low income & low density neighborhood
  - Old housing stock
  - Abandoned homes & vacant parcels

	Bankhead	Atlanta
Population	6,873	455,004
% Black	80.7%	52.6%
Unemployment rate	20.1%	10.4%
Median HH income ($)	33,433	60,730
% Home ownership	26.0%	42.6%
Vacancy rate	34.2%	18.1%

Data: American Community Survey 5-year Estimates (2012-2016)

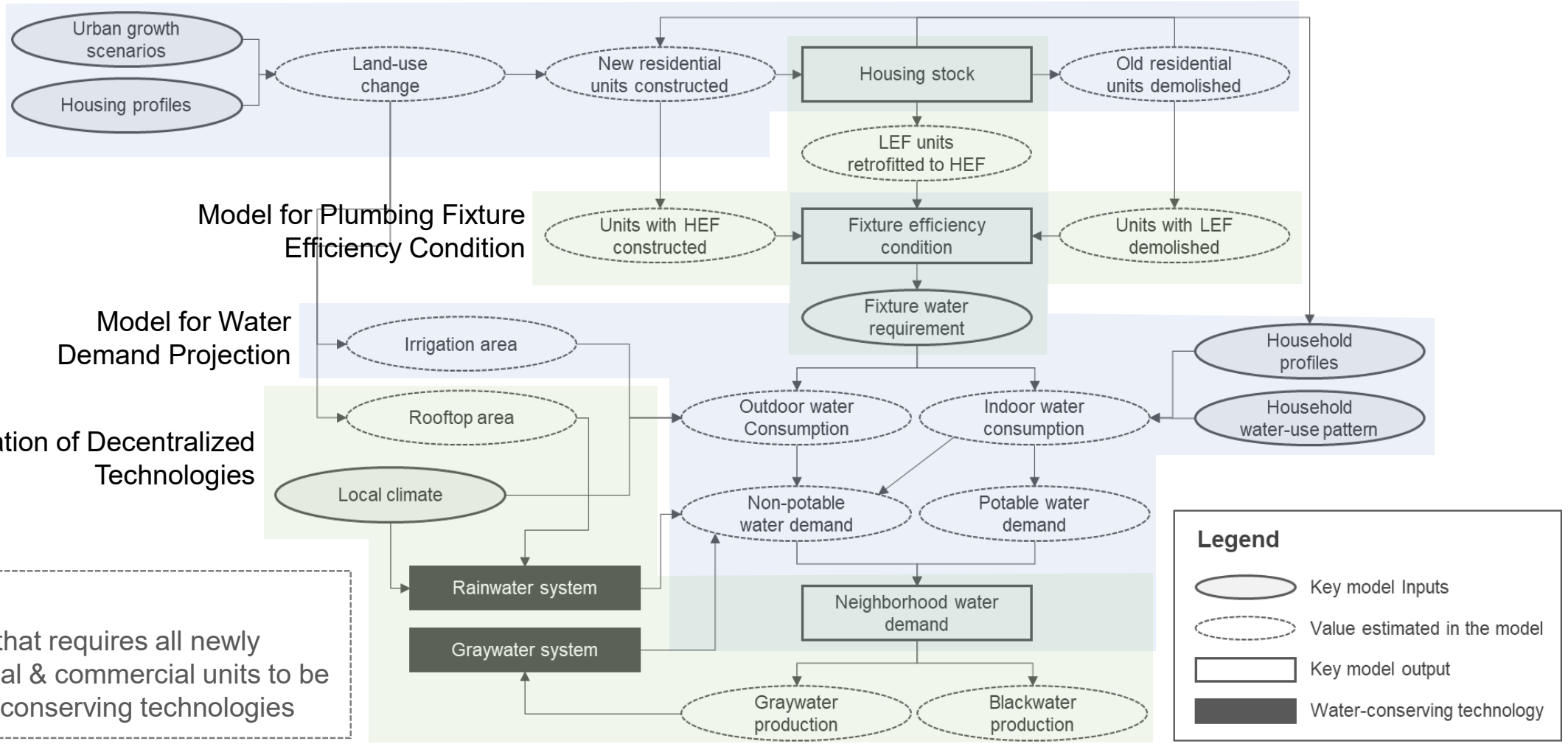
System Dynamics Model

Model for Housing Stock Dynamics

Model for Plumbing Fixture Efficiency Condition

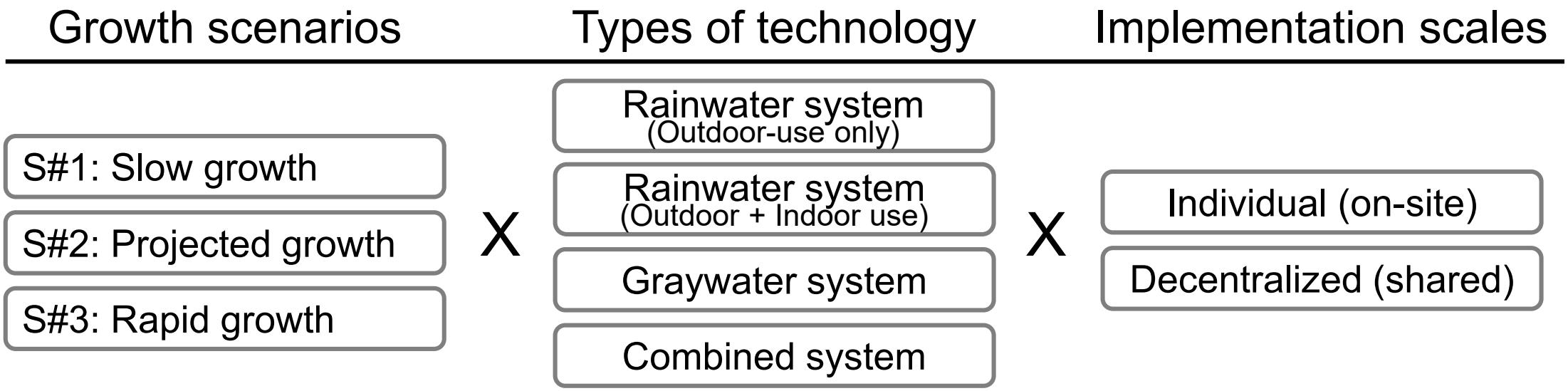
Model for Water Demand Projection

Evaluation of Decentralized Technologies



Assumption:
New plumbing code that requires all newly constructed residential & commercial units to be equipped with water-conserving technologies

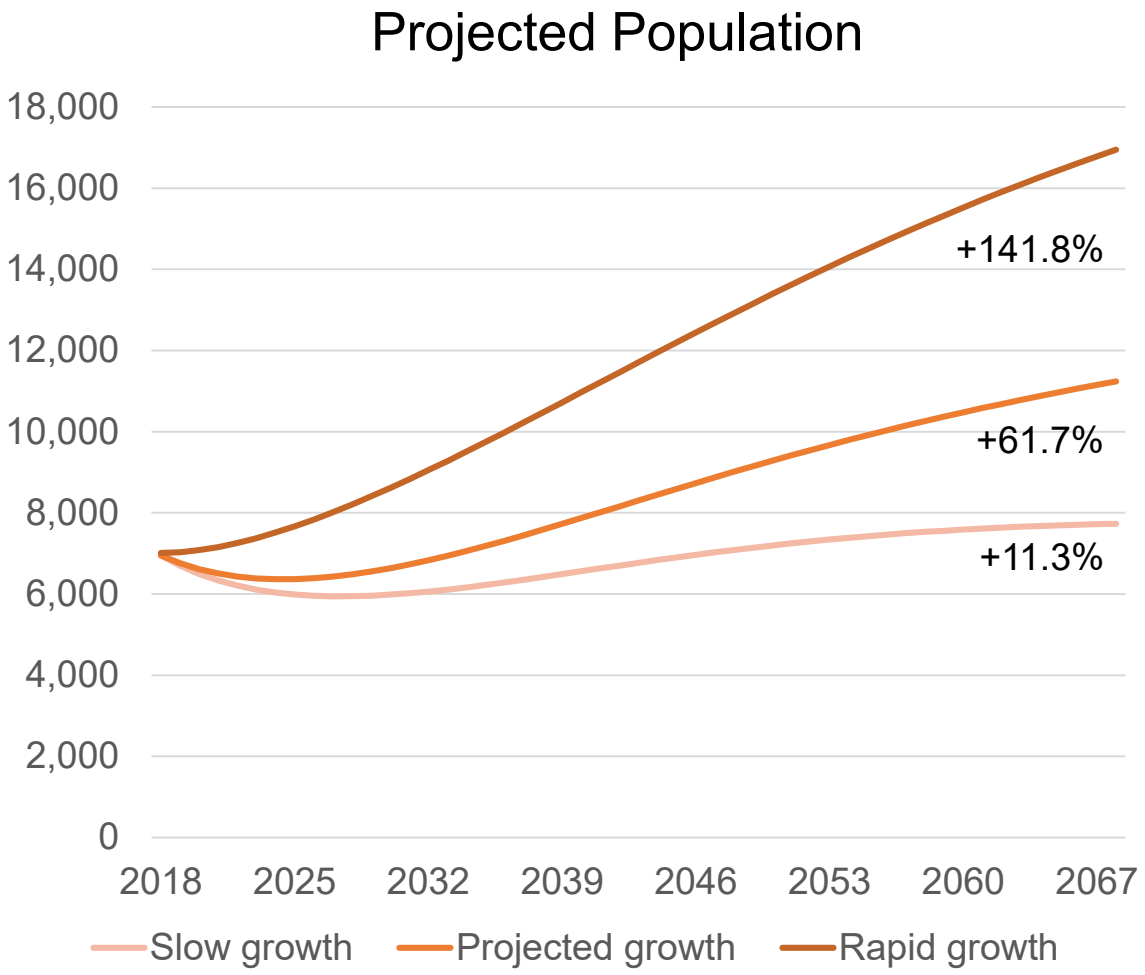
Testing Scenarios

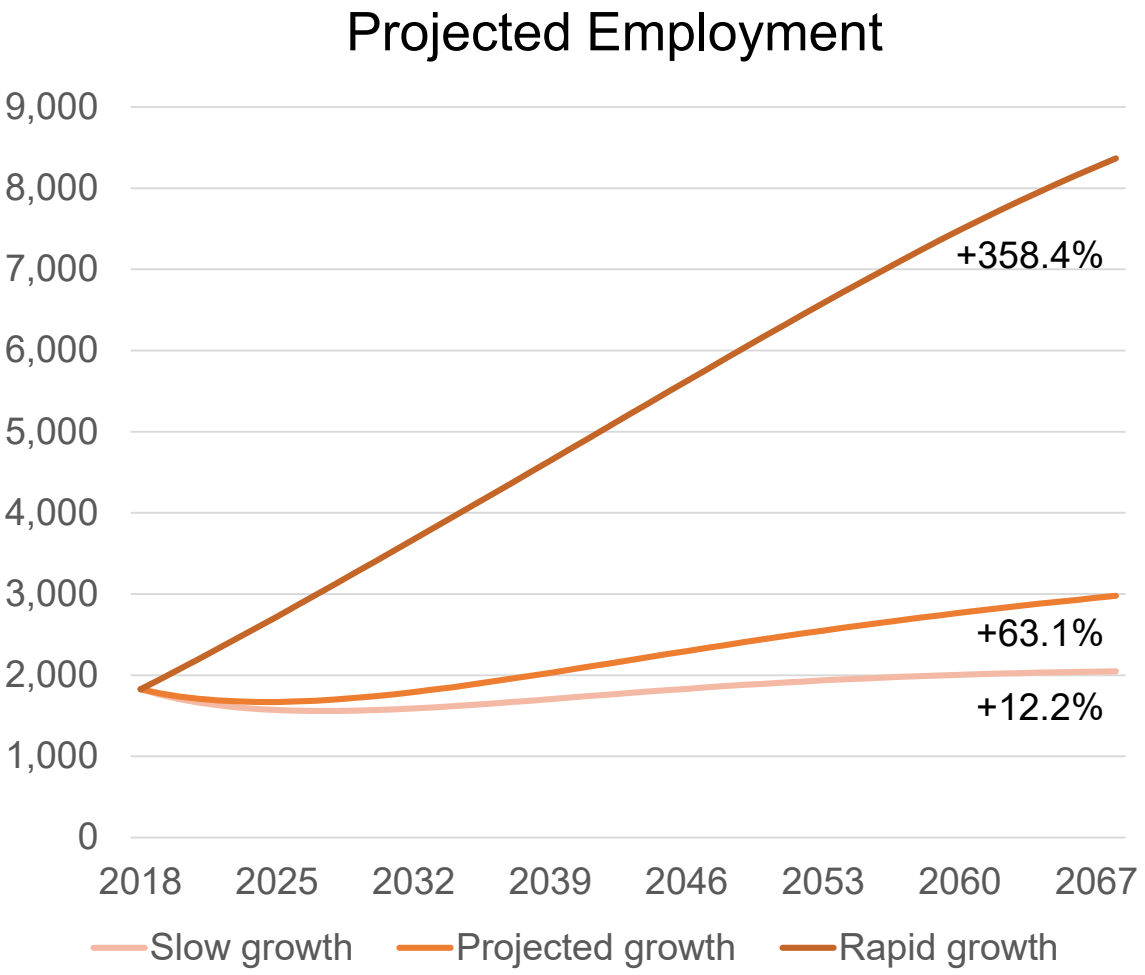


- Neighborhood Growth Scenarios

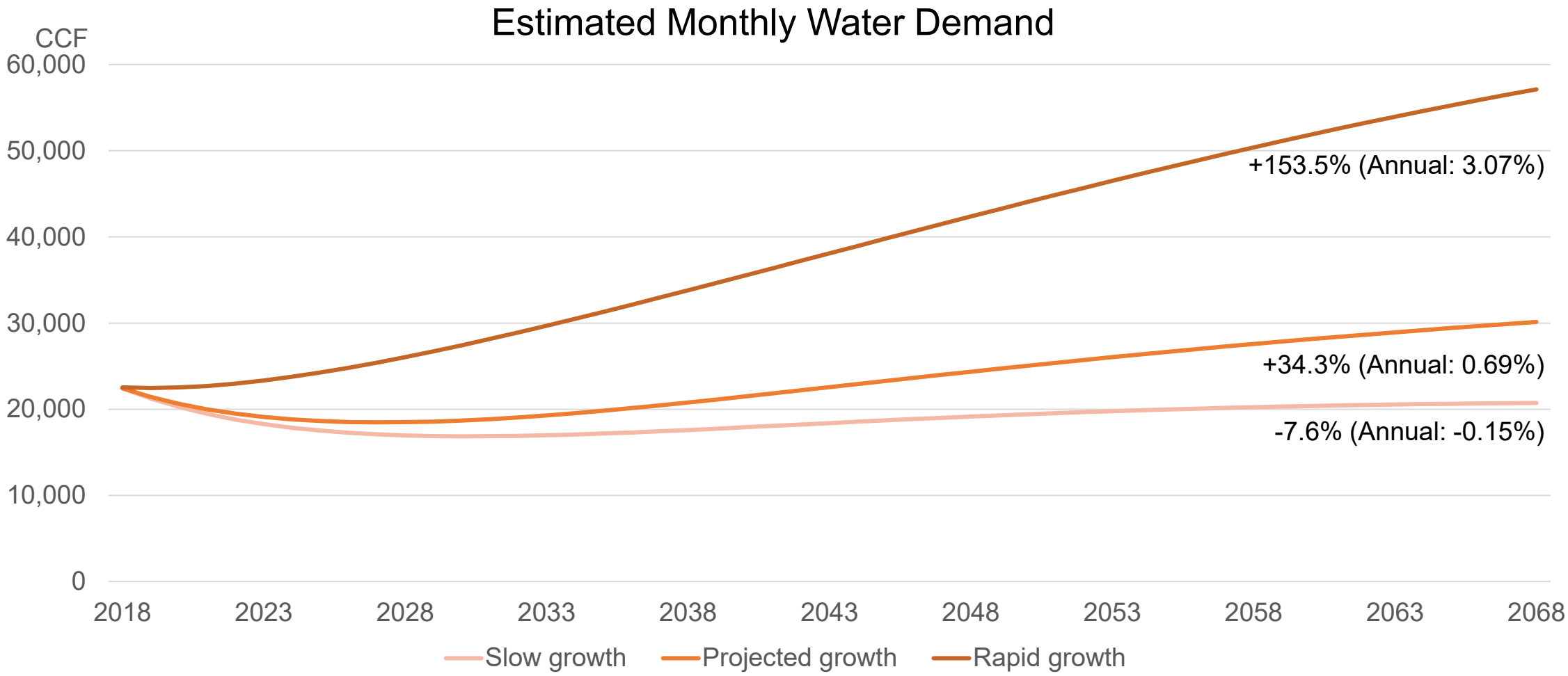
S#1: Slow growth	Land-use patterns and the vacancy rate will remain unchanged
S#2: Projected growth	The vacancy rate will decrease from 34.15% to 4.3%
S#3: Rapid growth	Benchmarking to another TOD neighborhood (Lindbergh)

Results: Population & Employment Change

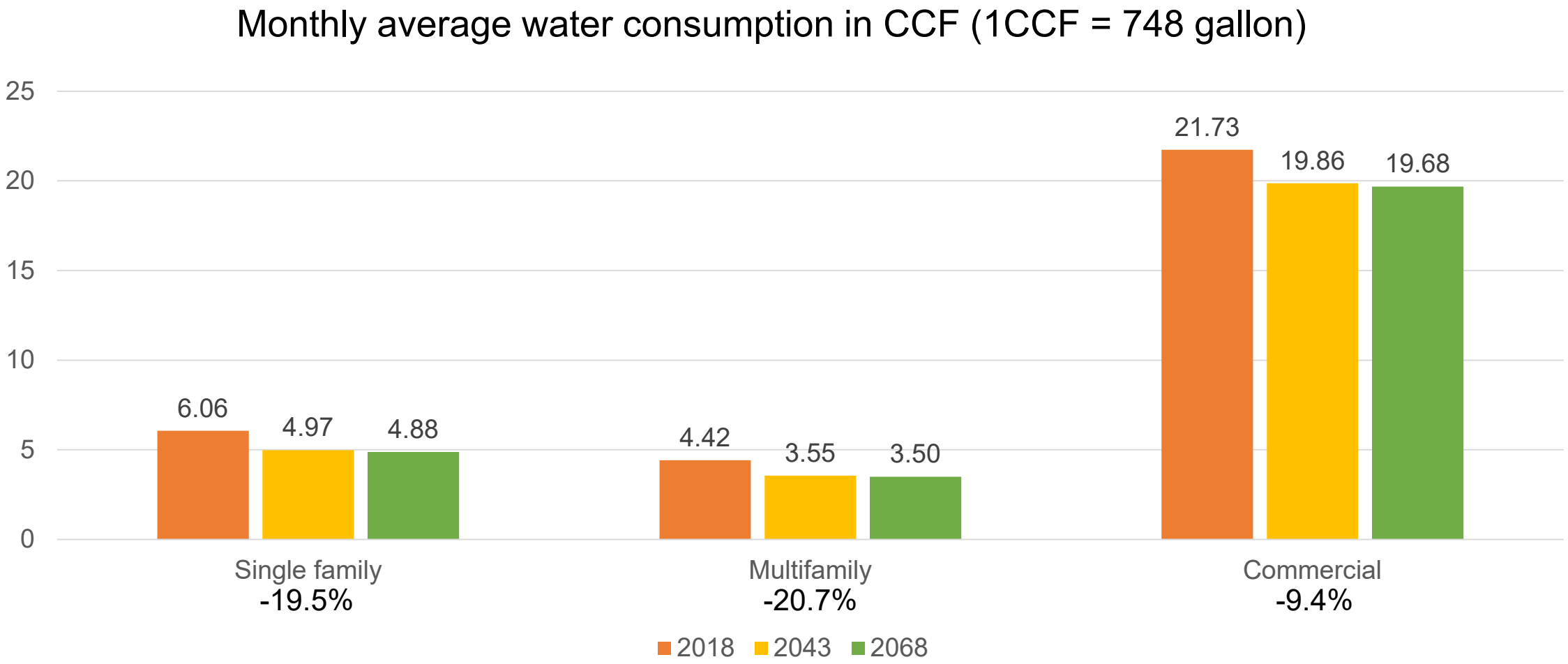




Results: Water Consumption Projection

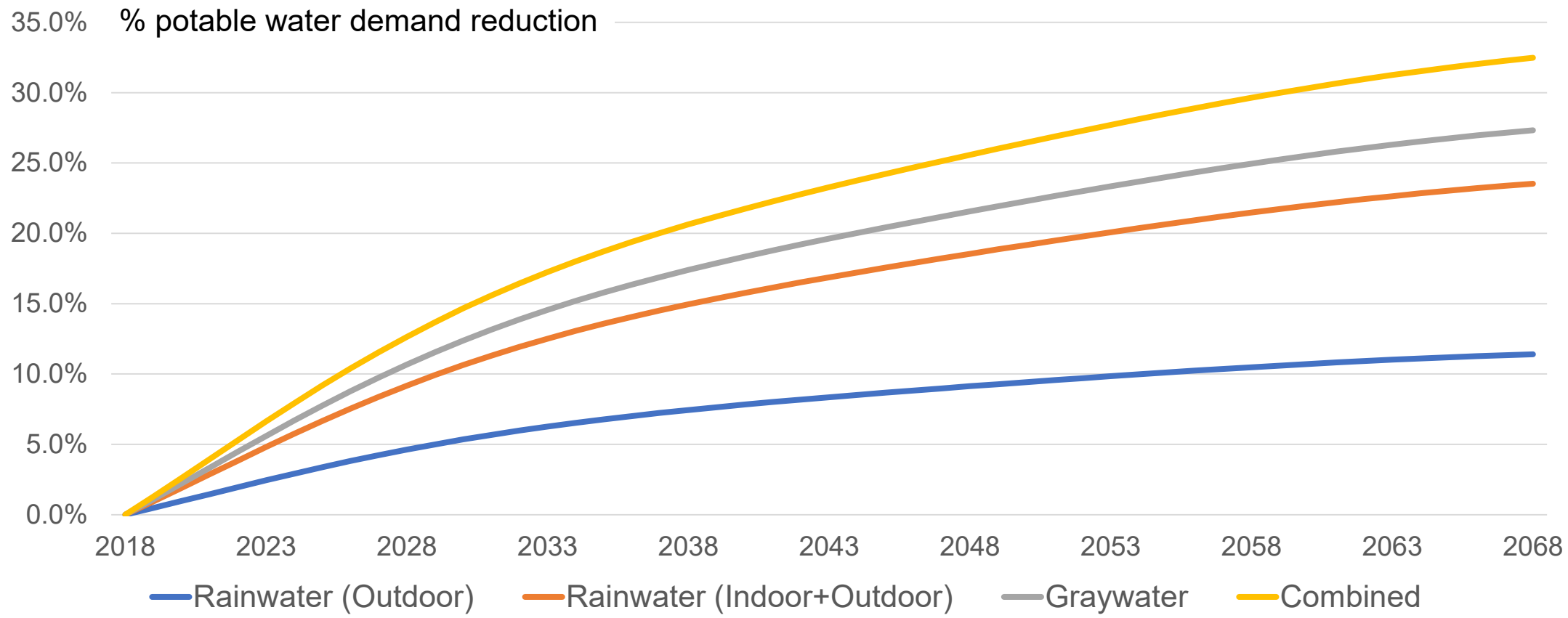


Results: Effect of Fixture Retrofitting (Water consumption per unit)



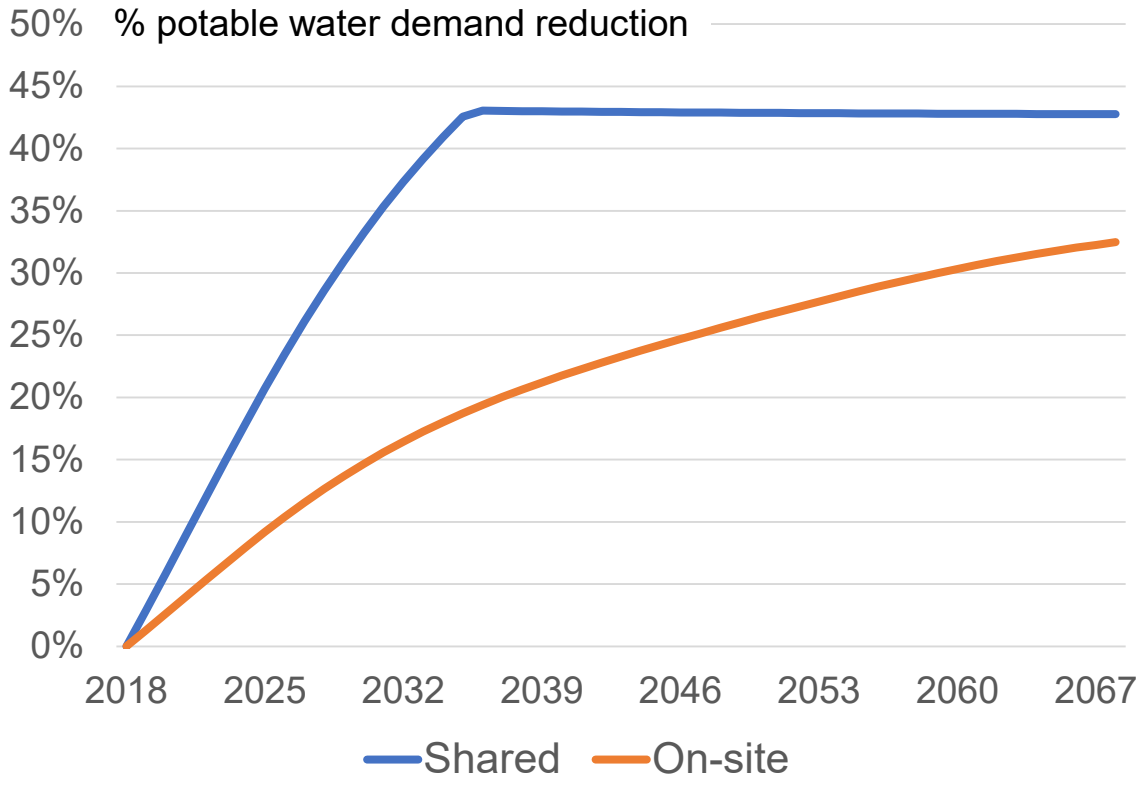
Results: Effect of Decentralized Technologies (Reduced water demand)

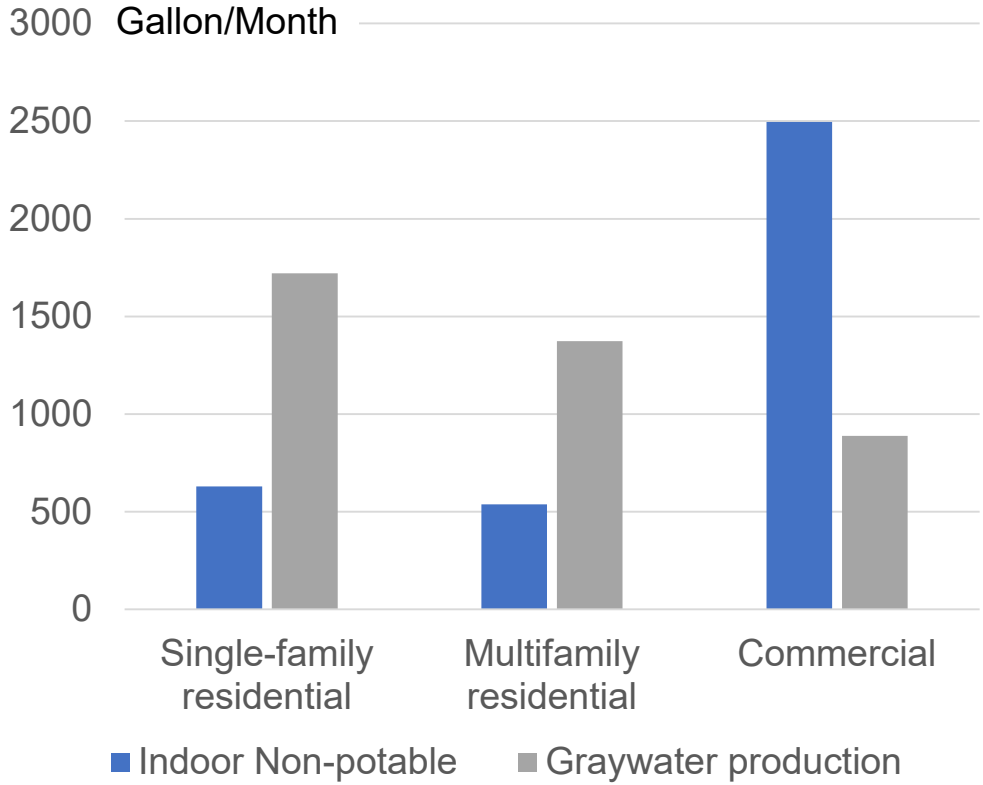
- Potable water reduction by technologies (Projected growth, on-site)



Results: Effect of Decentralized Technologies (Reduced water demand)

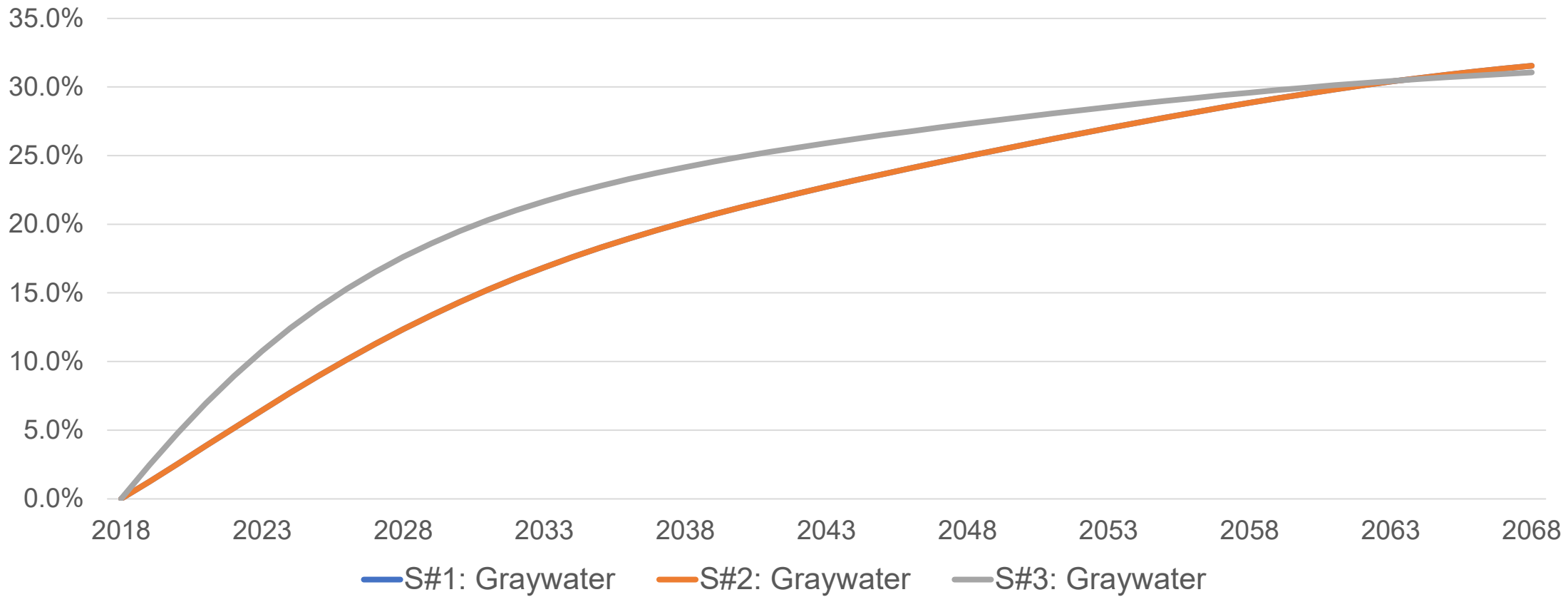
- Comparison between on-site and shared infrastructures (Projected growth, Combined system (RW+GW))





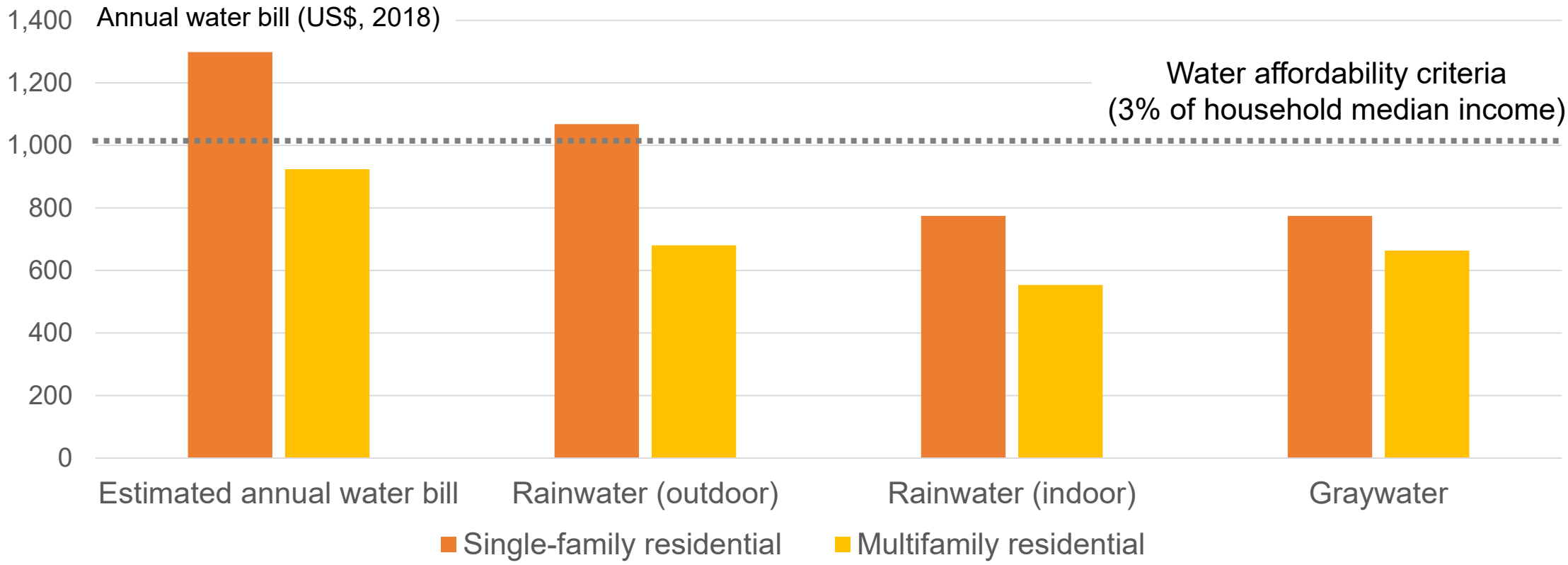
Results: Effect of Decentralized Technologies (Reduced wastewater)

- % wastewater reduction (Projected growth, Graywater (on-site))



Results: Effect of Decentralized Technologies (Reduced water bill)

- Estimated annual water bill (Projected growth, on-site technologies)



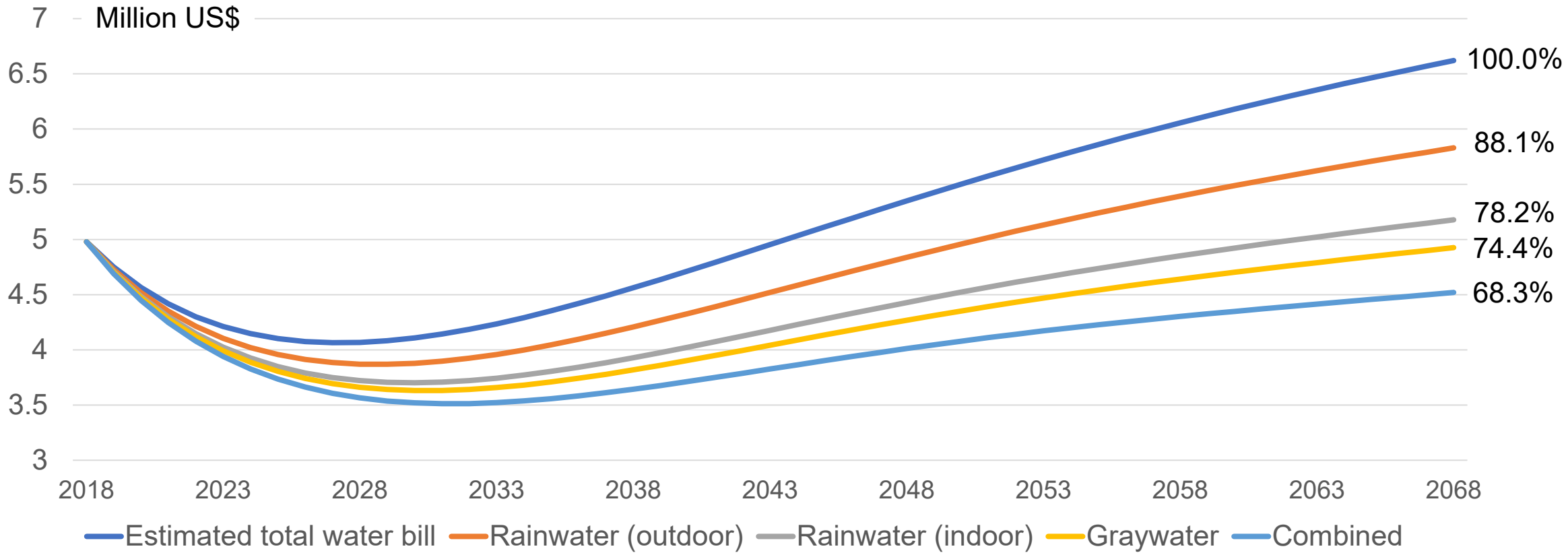
Results: Financial Implications of Decentralized Technologies

- Cost-Benefit analysis results for on-site technologies

	Single-family unit		Multifamily unit	
	NPV (US$)	BC-ratio	NPV (US$)	BC-ratio
Rainwater (outdoor)	-327	0.93	-18	0.97
Rainwater (indoor)	-1,156	0.87	46	1.02
Graywater	-2,347	0.77	238	1.10
Combined	-5,900	0.57	-128	0.95

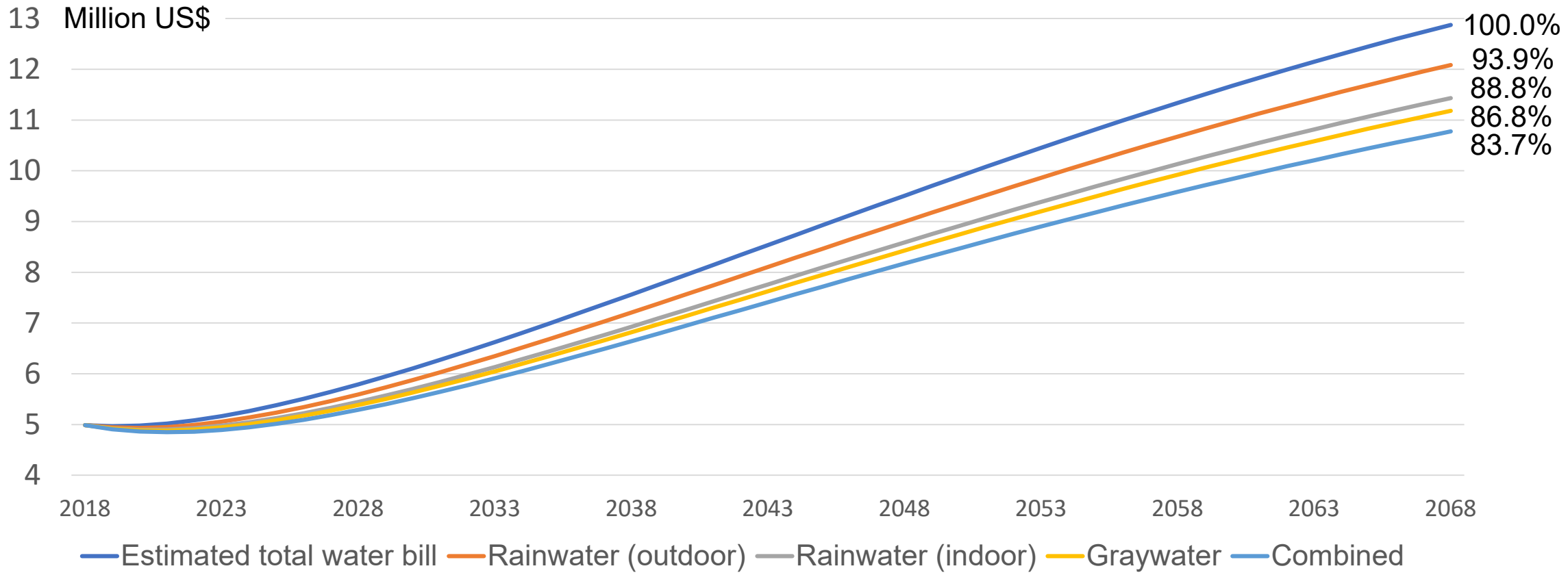
Results: Fiscal Impacts of Decentralized Technologies

- Annual revenue from potable and wastewater bill (Projected growth)



Results: Fiscal Impacts of Decentralized Technologies

- Annual revenue from potable and wastewater bill (Rapid growth)



Conclusion

- Decentralized water infrastructures are an effective solution to sustainable water management for growing urban neighborhoods.
  - Ecological benefits
    - Reduce 16.6 - 47.2% potable water consumption
    - Reduce 31.1 – 45.8% wastewater production
  - Social benefits
    - Greater water accessibility for households and businesses in low-income neighborhoods
- On-site water-conserving technologies may increase fiscal pressure of city's water department because of reduced service revenues.
  - For a growing city, increased water demand offsets the reduction in per capita water bill
  - Shared infrastructure is a better solution for a city in terms of effectiveness, efficiency, and fiscal control